prognosis after cardiopulmonary bypass: a meta-analysis of cohort studies[J]. Am J Kidney Dis, 2015, 65(2): 283-293.

[7] Gameiro J, Agapito Fonseca J, Jorge S, *et al*. Acute kidney injury definition and diagnosis: a narrative review[J]. J Clin Med, 2018, 7(10): 307.

[8] Tidbury N, Browning N, Shaw M, *et al*. Neutrophil gelatinase-associated lipocalin as a marker of postoperative acute kidney injury following cardiac surgery in patients with preoperative kidney impairment [J]. Cardiovasc Hematol Disord Drug Targets, 2019, 19(3): 239-248.

[9] Yoneyama F, Okamura T, Takigiku K, *et al*. Novel urinary biomarkers for acute kidney injury and prediction of clinical outcomes after pediatric cardiac surgery[J]. Pediatr Cardiol, 2020, 41(4): 695-702.

[10] Abu Alfeilat M, Slotki I, Shavit L. Single emergency room measurement of neutrophil/lymphocyte ratio for early detection of acute kidney injury (AKI)[J]. Intern Emerg Med, 2018, 13(5): 717-725.

[11] O'Neal JB, Shaw AD, Billings FT 4th. Acute kidney injury following cardiac surgery: current understanding and future directions[J]. Crit Care, 2016, 20(1): 187.

[12] Lannemyr L, Bragadottir G, Krumbholz V, *et al*. Effects of cardiopulmonary bypass on renal perfusion, filtration, and oxygenation in patients undergoing cardiac surgery[J]. Anesthesiology, 2017, 126(2): 205-213.

[13] Harky A, Joshi M, Gupta S, *et al*. Acute kidney injury associated with cardiac surgery: a comprehensive literature review [J]. Braz J Cardiovasc Surg, 2020, 35(2): 211-224.

[14] Rasmussen SR, Kandler K, Nielsen RV, *et al*. Duration of critically low oxygen delivery is associated with acute kidney injury after cardiac surgery[J]. Acta Anaesthesiol Scand, 2019, 63(10): 1290-1297.

[15] Mukaida H, Matsushita S, Kuwaki K, *et al*. Time-dose response of oxygen delivery during cardiopulmonary bypass predicts acute kidney injury[J]. J Thorac Cardiovasc Surg, 2019, 158(2): 492-499.

[16] Newland RF, Baker RA. Low oxygen delivery as a predictor of acute kidney injury during cardiopulmonary bypass[J]. J Extra Corpor Technol, 2017, 49(4): 224-230.

[17] Oshita T, Hiraoka A, Nakajima K, *et al*. A better predictor of acute kidney injury after cardiac surgery: the largest area under the curve below the oxygen delivery threshold during cardiopulmonary bypass[J]. J Am Heart Assoc, 2020, 9(15): e015566.

[18] Shaefi S, Mittel A, Klick J, *et al*. Vasoplegia After Cardiovascular Procedures-Pathophysiology and Targeted Therapy[J]. J Cardiothorac Vasc Anesth, 2018, 32(2): 1013-1022.

[19] Magruder JT, Crawford TC, Harness HL, *et al*. A pilot goal-directed perfusion initiative is associated with less acute kidney injury after cardiac surgery[J]. J Thorac Cardiovasc Surg, 2017, 153(1): 118-125.

[20] Ranucci M, Johnson I, Willcox T, *et al*. Goal-directed perfusion to reduce acute kidney injury: A randomized trial [J]. J Thorac Cardiovasc Surg, 2018, 156(5): 1918-1927.

[21] Schulte PJ. Questionable interim analyses in the goal-directed perfusion trial study of goal-directed perfusion [J]. J Thorac Cardiovasc Surg, 2019, 157(5): e277.

[22] Newland RF, Baker RA, Woodman RJ, *et al*. Predictive capacity of oxygen delivery during cardiopulmonary bypass on acute kidney injury[J]. Ann Thorac Surg, 2019, 108(6): 1807-1814.

[23] Hendrix RHJ, Ganushchak YM, Weerwind PW. Oxygen delivery, oxygen consumption and decreased kidney function after cardiopulmonary bypass[J]. PLoS One, 2019, 14(11): e0225541.

[24] Lukaszewski M, Lukaszewski R, Kosiorowska K, *et al*. The use of data science to analyse physiology of oxygen delivery in the extracorporeal circulation[J]. BMC Cardiovasc Disord, 2019, 19(1): 292.

[25] Fuhrman DY, Kellum JA. Epidemiology and pathophysiology of cardiac surgery-associated acute kidney injury[J]. Curr Opin Anaesthesiol, 2017, 30(1): 60-65.

[26] Sharma A, Chakraborty R, Sharma K, *et al*. Development of acute kidney injury following pediatric cardiac surgery [J]. Kidney Res Clin Pract, 2020, 39(3): 259-268.

[27] Agarwal HS, Wolfram KB, Saville BR, *et al*. Postoperative complications and association with outcomes in pediatric cardiac surgery[J]. J Thorac Cardiovasc Surg, 2014, 148(2): 609-616.

[28] Li D, Niu Z, Huang Q, *et al*. A meta-analysis of the incidence rate of postoperative acute kidney injury in patients with congenital heart disease[J]. BMC Nephrol, 2020, 21(1): 350.

[29] Ueno K, Shiokawa N, Takahashi Y, *et al*. Kidney disease: improving global outcomes in neonates with acute kidney injury after cardiac surgery[J]. Clin Exp Nephrol, 2020, 24(2): 167-173.

[30] Amini S, Abbaspour H, Morovatdar N, *et al*. Risk factors and outcome of acute kidney injury after congenital heart surgery: a prospective observational study [J]. Indian J Crit Care Med, 2017, 21(12): 847-851.

[31] Sugimoto K, Toda Y, Iwasaki T, *et al*. Urinary albumin levels predict development of acute kidney injury after pediatric cardiac surgery: a prospective observational study [J]. J Cardiothorac Vasc Anesth, 2016, 30(1): 64-68.

[32] Zhou RH. Critical indexed oxygen delivery as a cornerstone of goal-directed perfusion in neonates undergoing cardiac surgery. Comment on Br J Anaesth 2020; 124: 395-402[J]. Br J Anaesth, 2020, 125(3): e271-e272.

[33] Lannemyr L, Bragadottir G, Hjarpe A, *et al*. Impact of cardiopulmonary bypass flow on renal oxygenation in patients undergoing cardiac operations [J]. Ann Thorac Surg, 2019, 107(2): 505-511.

[34] Tadphale SD, Ramakrishnan K, Spentzas T, *et al*. Impact of different cardiopulmonary bypass strategies on renal injury after pediatric heart surgery [J]. Ann Thorac Surg, 2020. [Epub ahead of print].

[35] Bojan M, Gioia E, Di Corte F, *et al*. Lower limit of adequate oxygen delivery for the maintenance of aerobic metabolism during cardiopulmonary bypass in neonates[J]. Br J Anaesth, 2020, 124(4): 395-402.

[36] Matteucci M, Ferrarese S, Cantore C, *et al*. Hyperlactatemia during cardiopulmonary bypass: risk factors and impact on surgical results with a focus on the long-term outcome[J]. Perfusion, 2020, 35(8): 756-762.

(收稿日期:2020-11-30)
(修订日期:2021-01-13)

·综　述·

DOI: 10.13498/j.cnki.chin.j.ecc.2021.06.14

限制性输血策略在心脏外科围术期的研究进展

李娜娜,卢晓峰,李勇男,陶正泽,李俊伟,柳德斌

[摘要]: 目前国内外对于临床用血安全性及合理性的重视程度逐年增加,临床输血治疗逐渐由自由输血转化为限制性输血,由经验性转为科学性。心脏手术患者围术期输血的比例很大,本文就限制性输血在心脏外科围术期中的应用做一综述,为临床实践提供参考。

[关键词]: 心脏外科;限制性输血;自由输血;输血策略

Research progress of restricted blood transfusion strategy in perioperative period of cardiac surgery

Li Nana, Lu Xiaofeng, Li Yongnan, Tao Zhengze, Li Junwei, Liu Debin

Department of Cardiac Surgery, The Second Hospital of Lanzhou University, Gansu Lanzhou 730000, *China*

Corresponding author: Liu Debin, Email: ery_liudb@ lzu.edu.cn

[**Abstract**]: At present, domestic and international attention to the safety and rationality of clinical blood use has increased year by year. The treatment of clinical blood transfusion has gradually changed from liberal blood transfusion to restricted blood transfusion, from empirical to scientific.There is a large proportion of perioperative blood transfusion in patients undergoing cardiac surgery. This article reviews the application of restricted blood transfusion in perioperative cardiac surgery, in order to provide reference for clinical practice.

[**Key words**]: Cardiac surgery; Restrictive transfusion; Liberal transfusion; Transfusion policy

术前贫血在心脏外科中很常见,已有证据表明,术前贫血与患者术后不良结局有关[1-2]。输血是纠正贫血最迅速、最有效的方法,心脏手术患者围术期输血的比例很大[3-7],据报道,接受单纯冠状动脉旁路移植术的患者红细胞输注率高达 90%[8]。不同医院间的输血率在 8%~93%之间[7]。然而,输血是有风险的,随着对贫血和输血危害的更深入研究,限制性输血原则在心脏外科越来越受到关注,但目前仍缺乏统一的输血指导原则。

1 贫血及输血对心脏手术的影响

1.1 *贫血对心脏手术的影响及其原因* 在心脏外科手术中,术前贫血与患者的死亡率、输血率、危重症监护室(critically ill intensive care unit,CICU)停留时间和总住院时间等不良结局有关[1-2,9-14],但这些结论可能受到各种混杂因素的干扰。有研究表明术前贫血患者死亡率从 3.1%~45%不等[15-23]。由于这些文献中的研究对象术前贫血标准不一致,部分研究选择血红蛋白(hemoglobin,Hb)<100 g/L 或红细胞压积(haematocrit,HCT)<0.30 的重度贫血患者[2]。

还有一些研究[24]未将输血作为一个混杂因素加以控制,导致其结果可能存在偏差。Carson[25]等排除了这一影响,对拒绝输注红细胞患者的回顾性队列研究证实了患者死亡率随着术前 Hb 的降低而增加。现大多数据来自于接受单一手术方式的患者,而不是复杂的手术[19,21,23]。Padmanabhan[26]将接受多种类型心脏手术的患者纳入研究,结果显示:贫血患者较匹配的非贫血患者预后更差;多因素回归分析显示:术前贫血仍是导致急性肾损伤的独立预测指标(OR 1.76,95%CI:1.21~2.37, P =0.002)。Boening[27]等研究表明即使考虑到贫血患者围手术期的其他风险(高龄、心房颤动、糖尿病等),术前贫血也使死亡率增加了 3.7 倍。此外,围手术期发生重大不良心脑血管事件的风险增加了 2.2 倍。von Heymann[9]证明术前贫血患者早期和晚期死亡率均显著高于术前非贫血患者。

术前贫血对手术预后的不良影响是多因素的。

作者单位: 730000 兰州,兰州大学第二医院心脏外科

①接受心脏手术的患者更易受到术前贫血的影响，他们潜在的心脏储备不足，术中失血量大，输血的概率更大；在易受感染的患者中，输血可因三磷酸腺苷、2,3-二磷酸甘油酸水平的耗尽和红细胞的形态学改变严重限制氧气向组织的输送[28]。②贫血患者患糖尿病和肾病等疾病的发病率很高，这使他们不良预后的风险更高。③有证据表明心肺转流（cardiopulmonary bypass，CPB）中血液稀释会导致组织缺氧和术后肾损伤[15,29-30]。

1.2 *输血对心脏手术的影响* 输血是心脏外科纠正贫血最常用的方法，然而输血是有风险的，包括急性溶血反应和非溶血反应，病毒和细菌等疾病的传播。在既往研究中，输血患者的死亡率明显高于非输血患者[31-32]（P <0.0001），即使接受 1 单位红细胞输血的患者，术后死亡率也增加了 77%。输血带来的非传染性风险，如输血引起的急性肺损伤，在心脏手术患者中发生的频率更高[33]，这可能是由于心脏手术引起的全身和肺部炎症增加[34]，并可导致 5%～13% 的病死率[35-36]。但针对贫血和心肌梗死患者的一些研究则表明输血可能是有益的（OR 0.42，95%CI：0.20～0.89）[37]，尤其是对于 65 岁以上的患者（OR 0.69，95% CI：0.53～0.89）[38]。如何去平衡贫血与输血带来的风险尚无定论。

2 心脏外科输血阈值的变化

红细胞输血阈值定义为患者输血时的临界 HCT/Hb 或者红细胞体积。Hb 浓度作为输血阈值的设定一直以来颇具争议。最早被广泛接受的临床输血标准是 Hb 水平下降到 100 g/L 以下或 HCT 降到 0.30 以下。Adams and Lundy 于 1942 年首次提出“10/30 规则”[39]，数十年后，为了研究影响临床医生输血决定的因素开始引入“输血阈值”一词，即在 Hb 浓度低于某一临界值应给予输血治疗。随后，根据美国国立卫生研究院共识会议报告[40]，指南推荐可根据共患疾病的存在情况使用范围在 60 g/L 至 100 g/L 之间的 Hb 值[41-43]。限制性输血阈值是指较低的 Hb 值即给予患者输血治疗，美国血库协会指导方针建议在大多数临床环境中使用 70 g/L 到 80 g/L 的限制性输血阈值[43]。自由输血阈值指较高的 Hb 水平值开始输血治疗，最常见的是 90 g/L 至 100 g/L。在一项研究心脏外科限制性输血策略与自由输血策略的 meta 分析中[44]，纳入了 13 篇随机对照试验，其中 8 篇成人试验限制性输血阈值采用 Hb 70～90 g/L 或 HCT 0.24，自由输血阈值采用 Hb 85～100 g/L 或 HCT 0.28～0.30，5 篇未成年人试验限制性输血阈值采用 Hb 70～90 g/L，自由输血阈值采用 Hb 95～130 g/L。

3 心脏外科中的输血策略

红细胞输血与患者不良结局有密切关系，限制性输血原则也越来越受到医护人员的关注，限制性输血策略与自由输血策略的安全性和有效性也因此一直备受关注，心脏术后输血需求试验[45]是第一个探讨择期心脏手术患者的围术期限制性红细胞输注策略与自由输血策略安全性的前瞻性随机对照试验，该试验得出两种策略在主要结局（包括 30 d 死亡率）、及次要结局方面均无显着性差异（P =0.85）。但是该研究发现在 Hb 浓度为 80 g/L 的情况下，心脏源性休克的风险会增加。同时该研究证明了既往心脏手术史、女性、术后乳酸值、CPB 持续时间、Hb 浓度基线值是红细胞输血的预测指标。输注红细胞的数量是导致不良结果的独立危险因素（HR 1.2；95%CI：1.1～1.4；P =0.002），其生存分析 Kaplan-Meier 显示：输注 5 个或更多红细胞单位与较高的死亡率相关。

随后 Murphy 等开展了输血指征阈降低试验 2[46]，试验验证限制性红细胞输血策略与自由策略相比，能否降低术后的发病率和医疗费用。结果证明限制性输血组输血率明显低于自由组（两组输血率分别为 53.4%和 92.2%），但是限制性输血组死亡率高于自由组（4.2% vs. 2.6%；HR 1.64；95%CI：1.00～2.67；P =0.045），造成这一现象的原因尚不清楚。心脏外科手术的输血要求Ⅲ试验[47]是一项多中心、大型、非劣效性随机对照试验，该试验结果认为从全因死亡率、脑卒中、心肌梗死、新发的肾功能衰竭伴透析方面考虑，限制性输血策略和自由输血策略同样安全有效，且限制性输血组节约了血资源，减少了患者输血的风险。一项亚组分析发现在 75 岁或 75 岁以上的患者中，限制性输血组的综合风险明显低于自由输血组（OR 0.70；95% CI：0.54～0.89）。

Shehata[44]等荟萃分析证明限制性输血策略并不会导致 30 d 死亡率（RR 0.96；95%CI：0.76～1.21）、心肌梗死（RR 1.01；95%CI：0.81～1.26）、肾功能衰竭（RR 0.96；95%CI：0.76～1.20）、中风（RR 0.93；95%CI：0.68～1.27）、感染（RR 1.12；95% CI：0.98～1.29）和心律失常（RR 0.97；95%CI：0.91～1.04）的风险增加，但限制性输血组输血率降低了约 30%（RR 0.69；95%CI：0.67～0.71）。目前的研究证明限制性输血策略在心脏外科某些方面是安全有效

的,但是尚未明确得出输血的安全阈值,况且大部分文献只涉及了具有中高危死亡风险的患者,所得出的结论可能并不适合所有患者。

4 总结与展望

目前大多数临床医生一致认为,当 Hb 浓度低于 60 g/L 时,患者的风险会增加;当 Hb 浓度超过 100 g/L 时,很少有非出血患者受益于红细胞输血。研究证明了限制性输血策略在心脏手术患者中是有效和安全的,并且限制性输血策略可以有效节约血资源,避免不必要的输血。口服铁替代疗法治疗围手术期贫血与输血相比,是一种安全、廉价、相对方便的治疗方法,术前使用促红细胞生成素是纠正贫血和减少心脏手术中异基因输血的有效方法。未来的研究还需要评估其他可能补充 Hb 浓度的生理参数,作为红细胞输血的更好的使发因素,同时可以将外科医生和麻醉师进行盲法治疗分配,并允许其他工作人员根据研究方案做出输血决定。目前研究对象主要为成年人,儿童和老年人为研究对象者甚少,且心脏手术类型主要指接受 CPB 的冠状动脉旁路移植术和/或瓣膜置换术,因此需要更多的试验指导不同人群、不同手术类型的限制性输血策略。

参考文献:

[1] Padmanabhan H, Siau K, Curtis J, *et al*. Preoperative anemia and outcomes in cardiovascular surgery: systematic review and meta-analysis[J]. Ann Thorac Surg, 2019, 108(6): 1840-1848.

[2] LaPar DJ, Hawkins RB, McMurry TL, *et al*. Preoperative anemia versus blood transfusion: which is the culprit for worse outcomes in cardiac surgery[J]? J Thorac Cardiovasc Surg, 2018, 156(1): 66-74.

[3] Aujla H, Wozniak M, Kumar T, *et al*. Rejuvenation of. allogenic red cells: benefits and risks[J]. Vox Sang, 2018, 113: 509-529.

[4] Blaudszun G, Munting KE, Butchart A, *et al*. The association between borderline pre-operative anaemia in women and outcomes after cardiac surgery: a cohort study[J]. Anaesthesia, 2018, 73(5): 572-578.

[5] Paone G, Likosky DS, Brewer R, *et al*. Transfusion of 1 and 2 units of red blood cells is associated with increased morbidity and mortality[J]. Ann Thorac Surg, 2014, 97(1): 87-93.

[6] Deng X, Wang Y, Huang P, *et al*. Red blood cell transfusion threshold after pediatric cardiac surgery: A systematic review and meta- analysis[J]. Medicine (Baltimore), 2019, 98(11): e14884.

[7] Kheiri B, Abdalla A, Osman M, *et al*. Restrictive versus liberal red blood cell transfusion for cardiac surgery: a systematic review and meta-analysis of randomized controlled trials[J]. J Thromb Thrombolysis, 2019, 47(2): 179-185.

[8] Ter Woorst J, Sjatskig J, Soliman-Hamad M, *et al*. Evolution of perioperative blood transfusion practice after coronary artery bypass grafting in the past two decades[J]. J Card Surg, 2020, 35(6): 1220-1227.

[9] vonHeymann C, Kaufner L, Sander M, *et al*. Does the severity of preoperative anemia or blood transfusion have a stronger impact on long-term survival after cardiac surgery[J]? J Thorac Cardiovasc Surg, 2016, 152(5): 1412-1420.

[10] Hogan M, Klein AA, Richards T. The impact ofanaemia and intravenous iron replacement therapy on outcomes in cardiac surgery[J]. Eur J Cardiothorac Surg, 2015, 47(2): 218-226.

[11] Hung M, Ortmann E, Besser M, *et al*. A prospective observational cohort study to identify the causes of anaemia and association with outcome in cardiac surgical patients[J]. Heart, 2015, 101(2): 107-112.

[12] Pala AA, Taner T, Tatli AB, *et al*. The effect of preoperative hematocrit level on early outcomes after coronary artery bypass surgery[J]. Cureus, 2020, 12(4): e7811.

[13] Klein AA, Collier TJ,Brar MS, *et al*. The incidence and importance of anaemia in patients undergoing cardiac surgery in the UK-the first Association of Cardiothoracic Anaesthetists national audit[J]. Anaesthesia, 2016, 71(6): 627-635.

[14] Dhir A, Tempe DK. Anemia and patient blood management in cardiac surgery-literature review and current evidence[J]. J Cardiothorac Vasc Anesth, 2018, 32(6): 2726-2742.

[15] Loor G, Li L, Sabik JF 3rd, *et al*. Nadir hematocrit during cardiopulmonary bypass: end-organ dysfunction and mortality[J]. J Thorac Cardiovasc Surg, 2012, 144(3): 654-662.

[16] Cladellas M, Farre N, Comin-Colet J,et al. Effects of preoperative intravenous erythropoietin plus iron on outcome in anemic patients after cardiac valve replacement[J]. Am J Cardiol, 2012, 110(7): 1021-1026.

[17] Fowler AJ, Ahmad T, Phull MK, *et al*. Meta-analysis of the association between preoperative anaemia and mortality after surgery[J]. Br J Surg, 2015, 102(11): 1314-1324.

[18] Feneck RO. Anaemia and cardiac surgery[J]. Anaesthesia, 2016, 71(6): 611-613.

[19] Oprea AD, Del Rio JM, Cooter M, *et al*. Pre-and postoperative anemia, acute kidney injury, and mortality after coronary artery bypass grafting surgery: a retrospective observational study[J]. Can J Anaesth, 2018, 65(1): 46-59.

[20] Padmanabhan H, Brookes MJ, Nevill AM, *et al*. Association between anemia and blood transfusion with long-term mortality after cardiac surgery[J]. Ann Thorac Surg, 2019, 108(3): 687-692.

[21] Gao Z, Qin Z, An Z, *et al*. Prognostic value of preoperative hemoglobin levels for long-term outcomes of acute type B aortic dissection post-thoracic endovascular aortic repair[J]. Front Cardiovasc Med, 2020, 7: 588761.

[22] Paparella D, Guida P, Scrascia G, *et al*. On-pump versus off-pump coronary artery bypass surgery in patients with preoperative anemia[J]. J Thorac Cardiovasc Surg, 2015, 149(4): 1018-1026.

[23] Kwok CS, Tiong D, Pradhan A, *et al*. Meta-analysis of the prognostic impact of anemia in patients undergoing percutaneous coronary intervention[J]. Am J Cardiol, 2016,118(4): 610-620.

[24] Ranucci M, Di Dedda U, Castelvecchio S, *et al*. Impact of preoperative anemia on outcome in adult cardiac surgery: a propensity-matched analysis[J]. Ann Thorac Surg, 2012, 94(4): 1134-1141.

[25] Carson JL,Noveck H, Berlin JA, *et al*. Mortality and morbidity in patients with very low postoperative Hb levels who decline blood transfusion[J]. Transfusion, 2002, 42(7): 812-818.

[26] Padmanabhan H, Aktuerk D, Brookes MJ, *et al*. Anemia in cardiac surgery: next target for mortality and morbidity improvement [J]? Asian Cardiovasc Thorac Ann, 2016, 24(1): 12-17.

[27] Boening A, Boedeker RH, Scheibelhut C, *et al*. Anemia before coronary artery bypass surgery as additional risk factor increases the perioperative risk[J]. Ann Thorac Surg, 2011, 92(3): 805-810.

[28] Tinmouth A, Fergusson D, Yee IC, *et al*. Clinical consequences of red cell storage in the critically ill[J]. Transfusion, 2006, 46(11): 2014-2027.

[29] Hogervorst E, Rosseel P, Van der Bom J, *et al*. Tolerance of intraoperative hemoglobin decrease during cardiac surgery [J]. Transfusion, 2014, 54(10 Pt 2): 2696-2704.

[30] Vermeulen Windsant IC, de Wit NC, Sertorio JT, *et al*. Hemolysis during cardiac surgery is associated with increased intravascular nitric oxide consumption and perioperative kidney and intestinal tissue damage[J]. Front Physiol, 2014, 5: 340.

[31] Vlot EA, Verwijmeren L, van de Garde EMW, *et al*. Intra-operative red blood cell transfusion and mortality after cardiac surgery [J]. BMC Anesthesiol, 2019, 19(1): 65.

[32] Redfern RE, Naimy G, Kuehne M, *et al*. Retrospective analysis of thromboelastography-directed transfusion in isolated CABG: impact on blood product use, cost, and outcomes[J]. J Extra Corpor Technol, 2020, 52(2): 103-111.

[33] Bosboom JJ, Klanderman RB, Zijp M, *et al*. Incidence, risk factors, and outcome of transfusion-associated circulatory overload in a mixed intensive care unit population: a nested case-control study[J]. Transfusion, 2018, 58(2): 498-506.

[34] Vlaar AP, Hofstra JJ, Determann RM, *et al*. Transfusion-related acute lung injury in cardiac surgery patients is characterized by pulmonary inflammation and coagulopathy: a prospective nested case-control study[J]. Crit Care Med, 2012, 40(10): 2813-2820.

[35] Vlaar AP, Hofstra JJ, Determann RM, *et al*. The incidence, risk factors, and outcome of transfusion-related acute lung injury in a cohort of cardiac surgery patients: a prospective nested case-control study[J]. Blood, 2011, 117(16): 4218-4225.

[36] Chan CH, Ziyadi GM, Zuhdi MA. Adverse outcomes of perioperative red blood cell transfusions in coronary artery bypass grafting in hospital universiti sains malaysia[J]. Malays J Med Sci, 2019, 26(3): 49-63.

[37] Sabatine MS, Morrow DA, Giugliano RP, *et al*. Association of hemoglobin levels with clinical outcomes in acute coronary syndromes[J]. Circulation, 2005, 111(16): 2042-2049.

[38] Simon GI, Craswell A, Thom O, *et al*. Outcomes of restrictive versus liberal transfusion strategies in older adults from nine randomised controlled trials: A systematic review and meta-analysis [J]. Lancet Haematol, 2017,4(10): e465-e474.

[39] Tomic Mahecic T, Dunser M, Meier J. RBC transfusion triggers: is there anything new[J]? Transfus Med Hemother, 2020, 47(5): 361-368.

[40] No authors listed. Consensus conference. Perioperative red blood cell transfusion[J]. JAMA, 1988, 260(18): 2700-2703.

[41] Carson JL, Grossman BJ, Kleinman S, *et al*. Red blood cell transfusion: a clinical practice guideline from the AABB[J]. Ann Intern Med, 2012, 157(1): 49-58.

[42] Qaseem A, Humphrey LL, Fitterman N, *et al*. Treatment of anemia in patients with heart disease: A clinical practice guideline from the American College of Physicians[J]. Ann Intern Med, 2013, 159(11): 770-779.

[43] Retter A, Wyncoll D, Pearse R, *et al*. Guidelines on the management of anaemia and red cell transfusion in adult critically ill patients[J]. Br J Haematol, 2013, 160(4): 445-464.

[44] Shehata N, Mistry N, da Costa BR, *et al*. Restrictive compared with liberal red cell transfusion strategies in cardiac surgery: a meta-analysis[J]. Eur Heart J, 2019, 40(13): 1081-1088.

[45] Hajjar LA, Vincent JL, Galas FR, *et al*. Transfusion requirements after cardiac surgery: the TRACS randomized controlled trial[J]. JAMA, 2010, 304(14): 1559-1567.

[46] Murphy GJ, Pike K, Rogers CA, *et al*. Liberal or restrictive transfusion after cardiac surgery[J]. N Engl J Med, 2015, 372(11): 997-1008.

[47] Mazer CD, Whitlock RP, Fergusson DA, *et al*. Restrictive or liberal red-cell transfusion for cardiac surgery[J]. N Engl J Med, 2017, 377(22): 2133-2144.

（收稿日期:2020-11-02）
（修订日期:2021-01-13）